

# Pathways to Reach the Net Zero Energy Building

## The waste treatment centre in Mercabarna, Barcelona. Case study

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*ABSTRACT: Mercabarna is Barcelona's central market, supplies fresh food to the metropolitan area and generates economic activity in all Catalonia, and other European markets. The seventy percent of solid waste generated in Mercabarna is nowadays recycled in the treatment centre called "Punt verd," that consumes lots of water and energy and causes at the same time trouble and foul smell in its surroundings. Our project works by designing a new roof to cover the existing installation, which would try to reduce the environmental impact caused by its activity, while improving its surrounding conditions: generate shadow that decrease the external temperature, improve the air quality by greening with aromatic plants, use and accumulate the rainwater which would be used in irrigation and cleaning, could be capable to produce enough electricity from the solar radiation that would balance the actual purchase of grid energy.*

*This paper moreover will report how this new skin would turn the existing industrial factory into a hybrid building that will have the capacity to supply, in total, the annual operating energy requirements of their industrial process, and would as well, reach the net zero energy building goal.*

*Keywords: Energy, Net Zero Energy Building, Designing process, Case Study*

### INTRODUCTION

It is generally accepted that the next energy crisis resulting from the shortage of energy provided by fossil fuels; will cause steadily rising prices of fossil fuels and the insecurity of supply in a geopolitical environment increasingly complex.

The threat also is generated in a scenario of global climate change: The increasing use of fossil fuels as a primary energy source has resulted in rising levels of carbon dioxide in the atmosphere. There is a scientific consensus based on scientific data as well as the conviction of many citizens that to mitigate its impact and to avoid a planetary collapse, the increase of average global temperature by 2050 should be limited to a maximum of 2 °C. To achieve this objective in the coming decades it should be reduced at least half of the emissions of greenhouse gases, which is a challenge for governments, society and future citizenship.

Buildings consume worldwide, around 40% of primary energy and in the future new buildings, a drastic reduction of CO<sub>2</sub> emissions is crucial. Consequently, major efforts to improve the energy savings and energy efficiency together with a substantial use of renewable energy is needed and constitute a central aim in modern sustainable architecture.

The "net zero, energy buildings" (buildings that intend to deliver as much or more energy than they use), are achievable by the combination of such .

The EU directive EPBD on Energy Performance of Buildings (2010/31/EU of May 19th 2010) pursues this objective and therefore urges the states members to ensure that by December 31 2020 (2018 those depending on public administrations) all new buildings in the European Union, shall be "nearly zero energy buildings".. The European Parliament recently approved a recast (1) that defines Net- Zero Energy Building as " ...a building where , as a result of the very high level of energy efficiency of the building , the overall annual primary energy consumption is equal to or less than the energy production from renewable energy sources on site , therefore..." , this objective will indeed change the way buildings are designed and constructed..

However, nothing is said of the built patrimony in EU during the extraordinary property boom of the last decades. In fact, during the next few years great effort must be focused on the energetic rehabilitation of this built architecture that includes residential buildings but also all kinds of facilities and industrial buildings as well.

Of paramount importance achieving such aims is the concept of: "the hybrid building": defined as such by Newton and Tucker (2009) (2), That has been the first step towards this goal, although they are not self Net-Zero Energy Buildings (NZEBS), they are able to generate energy (low or zero emissions) which returns to the public network while receiving the energy supply for operation.

This paper reports as an example the intervention in an existing industrial facility, the treatment centre called “punt verd” in Mercabarna, Barcelona’s central market which consumes lots of water and energy. The project consist of a designed roof to cover the existing installation. We paper on how this new skin would turn the existing industrial factory into a hybrid building that would have the capacity to supply, in total, the annual operating energy requirements of their industrial process, and therefore reaching the net zero energy building goals.

## DESIGN PROCESS

Mercabarna is located in Barcelona; next on the sea coastland, has a Mediterranean climate, receives a high level of solar radiation throughout the year and has high temperatures and high humidity during the summertime. The waste treatment facility has no protection and it is exposed to intense solar radiation, most of the year that generates uncomfortable working conditions basically because unpleasant odors are produced due to the accelerated decomposition of organic waste. The installation consumes a large amount of electrical energy to operate and it consumes much water for cleaning and maintenance. At night, also when waste treatment activities are developed it is poorly lit.



Figure 1: The waste treatment facility “punt verd”

## THE CONCEPTION OF THE PROJECT

In the conception of this project we have started by mimicking the nature; we have been inspired by the clouds metaphorically speaking, imitating its effects on buildings in terms of the reduction of solar radiation, shadow production, water storage and energy generation. For this purpose, it has been designed a new roof cover, which become a protection for the existing building that provides shade, temperates the climate conditions of their environment by decreasing levels of solar radiation; it also will transform the waste treatment plant into an hybrid building capable of, improve the air quality by greenering the roof with Mediterranean aromatics plants,

in addition to the use and storage of rainwater which would be used for irrigation and cleaning. Finally it also could be capable to produce enough electricity from the solar radiation that would balance the actual purchase of energy from the grid.

To achieve these effects, it has been designed a specialized cover: one part will be a completely opaque deck to allow protection from rain and generate shadow. This portion will preferably work to collect and transfer water into a storage tank.

Another part will be a great shady site allowing natural ventilation and regulating solar radiation, generating a partial shade and promoting thermo-ventilation processes to decrease ambient temperature and high humidity. Over the roofing screw where there are the best radiation conditions, without cast shadows, there will be placed the photovoltaic panels to produce electricity. In the remaining part is projected a green roof upholstered with aromatic plants. In addition to generate power and gather rainwater, air temperature decreases by the shadow and ventilation generated by the sea breeze, it will reduce the process of decomposition of organic waste and it diminish bad smell, this effect will be increased with the aromatic plants on the green cover. Also a low consumption night lighting will be placed under the roof cover.

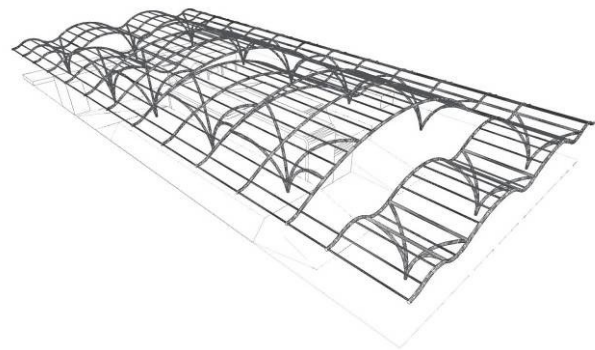


Figure 2: Structure of the new roof

## THE PROJECT OF THE NEW ROOF: DESIGN TOOLS

To design the shape of the cover the meteorological data of the site feeded the computer software, to simulate the ventilation conditions, lightning and cast shadows and to calculate the photovoltaic installation. The use tools were:

- Meteonorm for graphic climate generating.
- Phoenix for aerodynamic studies.
- Ecotect for sunlight.
- FV Expert for the photovoltaic installation.

According to the data provided by the property, the current installation of solid waste of Mercabarna “punt verd” the energy and water consumption are expressed in Table I.

Table 1: Current consumption of water and electricity

Year	electricity consumption kWh/year	water consumption m3/year
2007	231.344	1.113,00
2008	220.926	2.198,50
2009	219.124	1.642,15
2010	203.089	3.052,00
2011	226.428	2.896,00

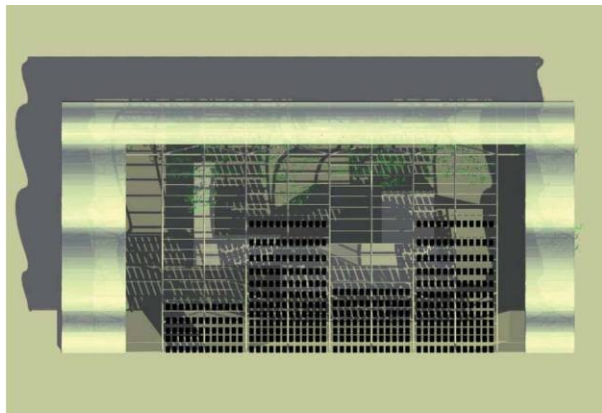


Figure 3: The project of the new roof

### THE PHOTOVOLTAIC INSTALLATION

A photovoltaic installation connected to the grid has been projected to generate the energy consumption of the “Punt verd” itself. For this matter a comparative study of the photovoltaic panel’s performance at different orientations has been made, taking into account the optimal area to fill with the solar collectors after studying the shadows projected on the deck.

To perform the calculations we took into account an average value of (220.000 kWh/year) according Table I .

To calculate the energy to be generated by the photovoltaic panels we have used the following parameters:

Inverter’s performance: 98%

Wiring losses: 10%

Energy to generate:  $220,000 \text{ kWh/year} / (0,98 \times 0,90) = 249,11 \text{ kWh/year} \rightarrow 250.000 \text{ kWh/year}$  of installed peak power.

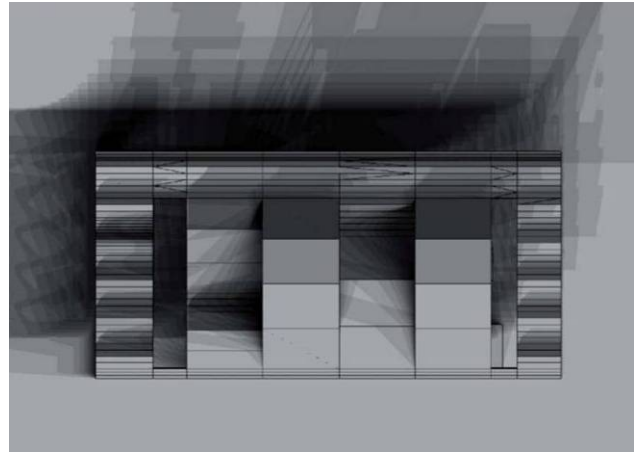


Figure 4: Shadow simulation on the covering

For the dimensioning of the photovoltaic installation have been used the following parameter:

Orientation of the collector: 35°

Photovoltaic monocrystalline panels of 230Wp power , up to an axis track, (this would allow a 20% increase in the performance relative to a fixed installation of the same power).

Efficiency: 14.1%

Dimensions of the panel: 1.580m x 1.069mm x 45mm (Surface = 1.69m<sup>2</sup>).

To supply the energy demand of “Punt verd”, using the Photovoltaic Panels up to an axis system, polar angle, we need a total of 585 panels measuring 1.6 x 1.0m, and a peak power of 230Wp. With all this we get the installation’s peak power of 134,55 kWp and will occupy a total area of about 1200m<sup>2</sup>.

The photovoltaic system connected to the public grid, designed for the installation’s project consists of a solar field with 585 panels connected in series of 15 panels, grouped in sets of 3 series, achieving with this a total of 134,55kWp. The modules on the cover are oriented to 30° and are endowed with a tracking axis structure, polar angle of the panel to optimize performance. After the panels, there are the power conditioning units formed by the protection equipment of the solar generator connected to each group of panels, the inverter and its equipment of protection and the counter, would be installed in the back area of the facilities, where the connection to the grid must take place. This unit will transform the continuous

electric current obtained from the panels into alternating electric current.

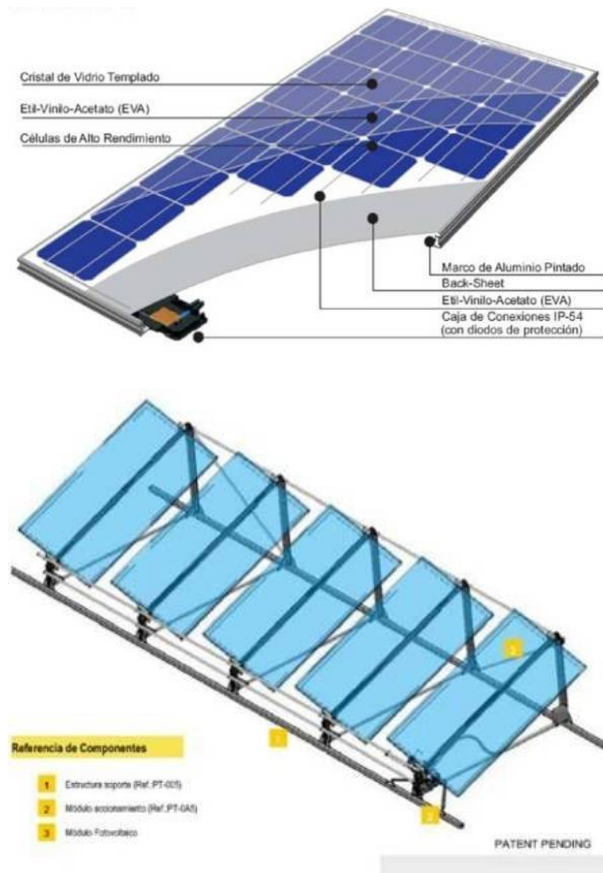


Figure 5: Image and structure of photovoltaic panels oriented to 30° with a single tracking axis

## RAINWATER COLLECTION AND ACCUMULATION SYSTEM

The rainwater collected on the roof will be used for cleaning and irrigation. The annual and monthly demand of "Punt verd" exceeds the supply of rainwater, and it would be necessary a supplementary contribution of water from the public supply system. The exclusive use for cleaning and irrigation simplifies the installation because it's not necessary to treat the gray water collected. The installation will have drain valves and an overflow connected to the sewerage network and water input to complement to the collected water on the cover and will incorporate a double safety system to avoid contamination of the potable water network with the gray water accumulated.

The primary elements of the system are:

**Gathering:** The surface to collect water will be of 1.643m<sup>2</sup>.

**Collection and direction:** a set of gutters located at low points of the cover, connected to the downspouts. Will have a rainwater outlet to prevent the blockage of the downpipes by solids (mainly vegetables waste). The **Interceptor:** Because the water collected will only be used for cleaning and irrigation, is not considered necessary the use of an interceptor.

**Accumulation:** The water will be stored into a polyethylene tank buried to avoid light (seaweed growth prevention) and high temperatures (for minimizing the bacterial growth). The tank will have: a self-cleaning filter at the entrance to prevent dirt from coming in. A water deflector to avoid the cause of eddies in the sedimentary deposit. A siphon prevent water ingress to cause eddies in the sediment, a siphon overflow anti-rodent, a floating suction system, level sensors to inform the management system and retention system with flow control.

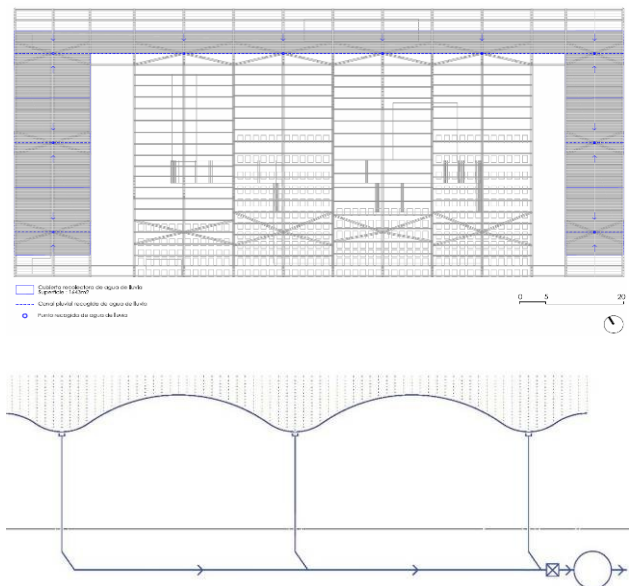


Figure 6: Rainwater collection and accumulation system

**Pumping:** Pumping system consisting of an energy efficient pump will distributes the water from the tank to the point of consumption.

**Management system:** Management system network between water and reservoir water will ensure the control on rainwater stored and will manage the automatic switching in between the water supply and the accumulated water in the tank.

## PLANT COVER OF AROMATIC SPECIES.

The green cover fits the modulated structure and cover part of the shady site, it will provides especial pots to plant climbing species. In these pots is placed one wire



mesh so that these plants may climb. Three plant species have been selected: *Trachelospermum jasminoides*, *Cestrum nocturnum* and *Lonicera japonica*. These plants are characterized by high growth rate at low humidity and high solar radiation. They are tolerant to drought and exhibit persistent leaves during the year, very aromatic especially during night and very long (5-10 meters). Although they are not native of the area, today are commonly used in Mediterranean areas to colonize walls and roofs.

The irrigation will be done with the rainwater collected on the roof and accumulated in a tank. The irrigation circuit, drop to drop, will rise from the pillars, located between the gathering area and the green cover, and will be distributed from the structural beams into the pots. The species have been selected in order to reduce water consumption because its can tolerate drought.

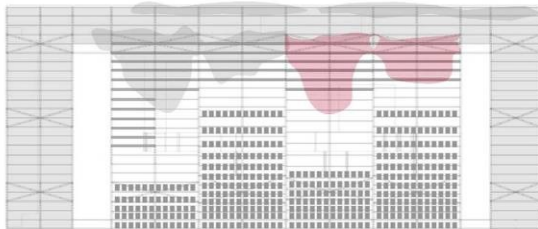


Figure 7: Improving the air quality greenering with aromatic plants, :*Lonicera japonica*, *Cestrum nocturnum*, *trachelospermum jasminoides*, etc.

## LIGHTING SYSTEM

The proposed lighting system is divided into two subsystems: The first one includes the areas of the facility “Punt verd,” which are illuminated yet in these areas we seeks to change the existing lighting systems for low consumption systems. The management system will provide with sensors for the detection of presence in the interiors zones of the buildings and control sensors of the luminous intensity in outdoor areas.

The second subsystem is directly related to the projected roof cover, and it is designed with the intention to provide general lighting of the facility area, especially in the working areas. Otherwise it try to light the roof cover structure using indirect illumination systems of LED color luminaries, giving color effects witch will convert the “punt verd in a point of reference. .

All the lighting installation would be characterized by low energy consumption, generating a reduction of the current electricity consumption in lighting up to 80%.

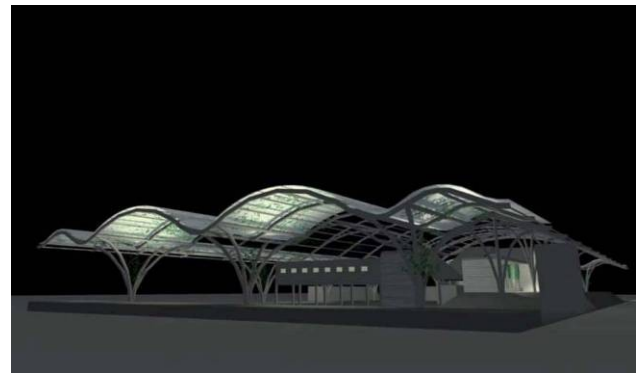


Figure 7. Night lighting conditions

## DISCUSSION AND CONCLUSION

In the climatic change era the built environment must incorporate sustainable strategies if we want to step on through a sustainable design model leading to zero energy buildings.

In this regard, the implementation of European Directive 2010/31 / EU on May 19, 2010 represents a new challenge in the way we designed the buildings so far and it introduces energy as a fundamental premise. And as shown in this paper this new way of thinking and designing is also applicable to the rehabilitation of the existing buildings. In any case this advanced energetic conception of Architecture using in the design process of bioclimatic design tools, energy efficiency with renewable energies and cyclic consideration of materials and water consumption is the appropriate way to reduce the carbon footprint and isn't an obstacle for designing, but an opportunity for creativity.

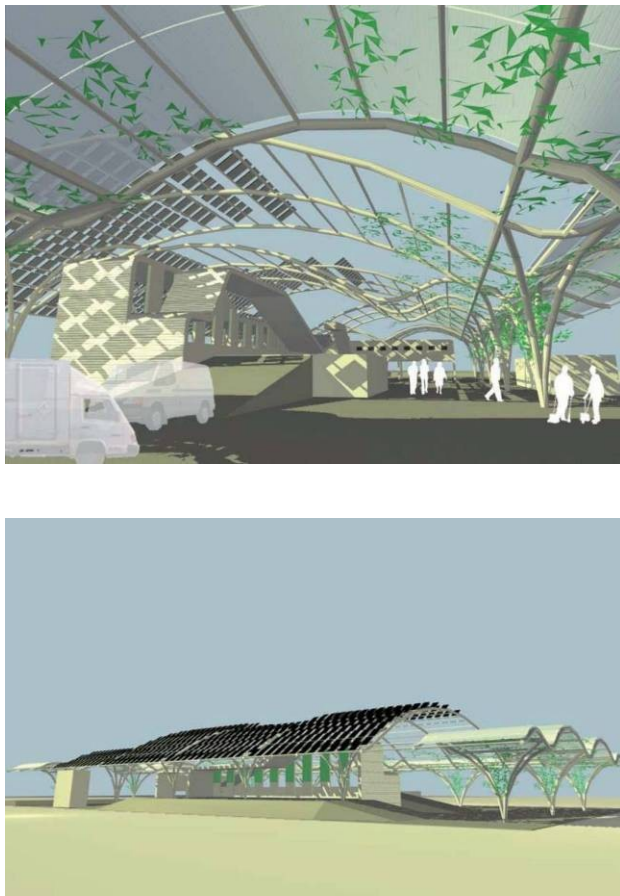


Figure 8: Rendering

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